

WDAN's New Dipole!

By Dan W1DAN

So my dipole antenna at the W1DAN radio facility had been in the air for over ten years. I started wondering if I could do better on 75 meters, the HF band I am on most often. This antenna started as a pre-made store bought multi-band dipole with 100 feet of 450 Ohm ladder line (like big TV twin-lead) and legs about 130 feet in total length. Because of the location of my tower and trees, I elected to use the tower near the house to support the center of the dipole at about 25 feet with the legs in a horizontal vee configuration. With my yard, I could only install it this way, with one leg up only ten feet to a tree in my yard. My neighbor allowed me to put the other leg in his tree about 30 feet up. While not an optimum installation, it worked pretty well. Soon after I installed this antenna, I realized that I had about 70 feet of "extra" ladder line in the shack. I got tired of seeing it, so one day I trimmed the extra feedline off and re-tuned my tuner. Remember this fact for later!

Ladder line dipole-photo by WB0JNR

The ladder line dipole ("zepp") antenna is a popular dipole because it works on all HF bands with the help of an antenna tuner (I use an MFJ tuner, which has a toroid balun to feed the dipole). Balanced antennas were more popular in the 1930s and 1940s before coax became prominent.

A "Zepp dipole" (image from http://www.qsl.net/ta1dx/amator/practical_dipole_antenna.htm)

So, this spring I decided to replace the dipole with a new one. In the interest of science, I wanted to measure my old antenna and try to quantify what it really was and determine any potential improvement. With this venture, I got the help of WARS member Larry K1QW, now located in Austin, Texas. In the meantime I found two items at last year's Near-Fest ham flea in New Hampshire to assist my venture. The first was an MFJ 209 antenna analyzer purchased for \$20.00. The second was an old 1950s Heath AM-1 impedance bridge, bought for 50 cents.

To add to this was a military AN-PRM10 grid dip meter from the USS Lawe (a Navy Destroyer) donated by Scott WO1G.

Finally assisting in measuring things, Peter W1ZZZ loaned me his MFJ 259 antenna analyzer.

Using my measurements, Larry modeled what I had and have me new models to think about.

Larry used EZNEC to first model the existing dipole. He determined that my slicing off most of my feedline drastically affected the impedance of my dipole at my operating frequency of 3.880Mhz. This was new to me as I always thought that transmission line (coax or ladder line) would provide the same antenna impedance at the antenna tuner or radio. This worked in my job as a TV engineer where we use 75 ohm coax to move video. Here the source impedance is 75 ohms and the end of 75 ohm coax is terminated in a 75 ohm resistor. Well, the resonance of my dipole was not anywhere near the desired 3.880 Mhz!

Let's talk about the test devices!

Most of my career I had inexpensive SWR bridges. I even have one in the MFJ tuner. This shows forward reflected voltage and allows one to adjust the antenna tuner to match (i.e. transform) the antenna impedance to the radio's nominal 50 ohms. These are reliable and simple devices that work well. Everyone should have an SWR bridge in line.

The MFJ 209 antenna analyzer I bought at Near-Fest is an older independent testing device that does not need a radio to generate a signal for testing. It has a wide range analog variable frequency oscillator and contains a Wheatstone bridge to determine reflected voltage at any frequency. This unit allows one to very quickly determine the resonant frequency of an antenna (or other tuned circuit, such as an antenna tuner), but does not show impedance. I use an external frequency counter to get accurate frequency readings with the analyzer. To get an impedance value, I use Peter's MFJ-259 analyzer. The MFJ-259B is the most popular analyzer today and contains an internal frequency counter as well as a circuit for measuring complex (inductance and capacitance) impedance in the HF through VHF range. Included are SWR and impedance meters.

This unit is handy when you are up on a roof or tower as everything is in one box. I prefer this unit, but they are still expensive at about \$300, and I am too cheap to buy one!

The Heathkit AM-1 antenna impedance meter is a simple passive RF Wheatstone bridge designed for a wide range of impedances, but needs an external RF signal to run it. A sensitive meter measures any imbalance across the bridge as created by an antenna.

There are an input set of terminals for a signal source and a set of antenna terminals. Most people use a Grid-Dip-Oscillator ("GDO"), such as the AN-PRM-10 or most often a Heath GDO to feed the input, which together function just like the MFJ-209, but use tubes. Scott WO1G gave me a very nice AN-PRM-10 GDO that covers HF to UHF and is pretty stable. This GDO uses plug-in coils and he used it to make many VHF and UHF antennas for himself and with our club members in the 80s. The Grid Dip Oscillator is just an oscillator feeding an external coil. When an external circuit is at resonance, part of the signal is "removed" or attenuated from the GDO coil, and this is reflected in the GDO meter, which indicates resonance of an external antenna or tuned circuit.

The AM-1 to me is the fun item in the group, as it was so inexpensive and not many are around. With a signal from the GDO, one sweeps the frequency to find the antenna resonance, then adjusts the knob to bring the bridge into balance and thus to determine the impedance. A more accurate way to determine exact impedance is to then replace the antenna with a variable resistor on the AM-1's output terminals and adjust to find the same meter reading. Then just measure this external resistance using an ohm meter or DVM. The GDO and AM-1 works well with balanced antennas, but are a bit difficult to use. With this system I was able to quantify my balanced dipole and feedline. The MFJ-209 and 259 antenna analyzers can barely make 450 ohms, but are really designed for today's common 50 ohms unbalanced equipment.

Computer Aided Design to the rescue!

Larry bought a copy of EZNEC (<http://www.eznec.com/>) antenna design software, and wanted to experiment with it. EZNEC is a

Windows application that allows one to see gain, azimuth, elevation, impedance and bandwidth of single and multi-element antennas from the comfort of your easy-chair. There is a \$99 version, a \$150 version and finally pro \$500 and \$600 versions. BUT!...there is a free version where you can model simple antennas, and a paid version where you can do multi-element antennas such as yagis. Larry offered to spend time modeling my current dipole, and I was surprised that my measurements matched his modeling in EZNEC pretty accurately! Larry also dabbled in Transmission Line for Windows (TLW) that is bundled with many ARRL Handbooks. Larry then designed a couple of dipoles for me to choose from. I picked the second design and bought wire, insulators, RG8X fifty ohm coax and rope.

With all this background, in May I performed some tests:

With the MFJ-209 analyzer connected to original antenna shows perfect dip at 3.013mc. Using Peter's MFJ-259, the original antenna is perfectly resonant (1:1 SWR) at 2.984mc and 40 ohms (not 450 ohms of the feedline). At my interested frequency of 3.880mc, SWR is 13:1 and 400 ohms-not in resonance.

Using the AN-PRM-10 grid-dip meter, the resonance of original antenna was 2.975mc. The Heath AM-1 shows 100 ohms resistance of the antenna. I was able to match an external 500 ohm resistor to AM-1 knob 450 ohm position at 3.870Mc (i.e. I adjusted an external resistor to match the AM-1 reading when antenna was connected-this provided me with a measureable secondary reference). The AM-1 showed no match or dip with knob FCW (i.e. at 600 ohm position) at 3.880mc. I added about 25 feet of ladder line. Still could not resonate at 3.8mc. Got resonance at 2.61mc. Added another 20 feet of ladder line, almost get resonance at 4.3mc (knob at 250 ohm). Resonance at 4.1mc with knob at 150 ohm-matches external 110 ohm resistor.

So I added 100 feet of ladder line (now about 125 feet total). Grid dip shows resonance at 4.446mc and AM-1 knob is at 375 ohms, which really matches an external 440 ohm resistor.

With added 100ft of line, MFJ-259 shows resonance (1.6:1) at 3.573mc and 60 ohms. Small

dip at 4.5 Mhz, and a deep resonance (1:1) at 9.626mc at 45 ohms.

The result of all this measurement was that my original dipole was not resonant at the desired frequency. It must not be the most efficient...or is it?

On July 3, Larry sent me an email with computer modeling details:

Hey, Dan,

I'm getting a bit more familiar with EZNEC, so I took some of the measurements you made and thought I would compare them with EZNEC results. Very interesting!

First, I modeled your antenna the way I think you have it set up. If I'm grossly wrong, let me know and I can correct my model. I constructed a horizontal vee with the two legs of 14-ga wire each 65 feet long at a ninety-degree angle, all parallel to the ground. I assumed a height above ground of 30 feet. EZNEC allows you to pick several different kinds of ground, so I used moderately moist soil.

Looking into the feed point of the antenna (i.e., no transmission line, yet) EZNEC reports a resonance at 3.7 MHz and about 23 ohms impedance (Unexpectedly low!!). The elevation pattern shows most of the energy going up at fairly high angle -- above 45 degree elevation. Not so good for DX, but fine for local (NVIS) QSOs.

It was interesting to move the same model to free space (no ground nearby). The resonant frequency didn't change, but the feed-point impedance jumped up to about 50 ohms, like you'd expect, and the elevation pattern was perfectly round, with full field strength right down to zero elevation and below.

Next, I put the model back 30 feet from the ground and fed the antenna model with 100 feet of 450 ohm balanced line, so it's sorta like your real antenna. I was surprised to see the resonant point jump up to about 4.6 MHz, which is just what you observed, more or less. I fooled around with the model and found that resonance would move all over the place when I changed the length of the feedline. When the line length was less than 40 feet, a secondary resonance started to show up.

So, some of what you observed shows up in the EZNEC model -- I was glad to see that! Gives me a little confidence in my ability to use the software. I'm still looking at the results you sent me, so I

hope to find more interesting stuff.

This little exercise is also illustrates the point that the antenna, transmission line, ground conditions and anything else around are all part of one entire resonant system. So, it's hard to deal with these elements one-by-one.

Anyway, that's it for now. EZNEC lets you do quite a bit. It's fairly easy and it's fun to use. I intend to dig into this a lot more so if there's anything you want me to model for you (antenna configurations, AZ or EL patterns, etc.), let me know.

Keep the data flowing!!

73 to everyone,

Larry

In discussing ideas with Larry and reading online, I learned that a transmission line becomes a transformer when the antenna or load impedance is not matched to the line impedance. It is a transformer like a power or audio or RF one we are all familiar with. In the end my dipole was not resonant at the desired frequency, but these Zepp antennas are usually not. They are meant to be multi-band dipoles with the help of a tuner. Either way, many people heard me with good signal reports.

So my choice was to either add the correct length of balanced transmission line to return to the proper transformation, or to make a coaxial fed dipole and simplify feline issues and measurement verification for 75 meters. After testing with my three test devices, I decided to make a new coaxial fed dipole for just 75 meters and skip having an all-bander as I use my beam mainly on 20m and have not been on 40 in some time. This will simplify my measurements as the MFJ analyzers are really meant for 50 ohms unbalanced devices.

From an email, Larry states:

Hi, Dan,

After spending some time with EZNEC and reading the ARRL Antenna Book a couple of times, I'm beginning to understand a little bit more about antennas and xmission lines.

If you just want an antenna for a single frequency,

like 3880 kHz, and if you want to use coax for the feedline probably the most efficient setup is one that has a really low SWR, to keep line losses down.

Using EZNEC and TLW, I think that an all-coax system with a shorted matching stub would work. Looks like this:



EZNEC says this gives an SWR of 1.08-to-1 at 3.9 MHz, and the total losses in the coax is pretty low -- about 1 db. And only needs a coax T connector for the shorted stub.

There are probably a dozen other ways to do this, but this one looked interesting to me. It's almost exactly 50 ohms from the T connector on out. In the drawing I wrote "To Tuner" but you probably wouldn't need one, keeping the losses down even more -- just go right into the transceiver. Of course, this is only an EZNEC prediction and in reality all these lengths may need trimming.

Don't know if this answers any of your concerns, but it might be interesting to try and see how it works out.

If you are still interested in the horizontal Vee, I can model a feedline and stub for that too. Also, 450 ohm ladder line might be even a bit better than the coax. All kinds of possibilities arise!!

73,

Larry, K1QW

Of interest to Larry was the fact that my low antenna height of 30 feet brings down the impedance of the antenna from about 70 ohms to 30. After more emails, Larry supplied the following drawing.

I adjusted my model for 120 deg angle on the Vee, and using more accurate data for the RG-8x coax.

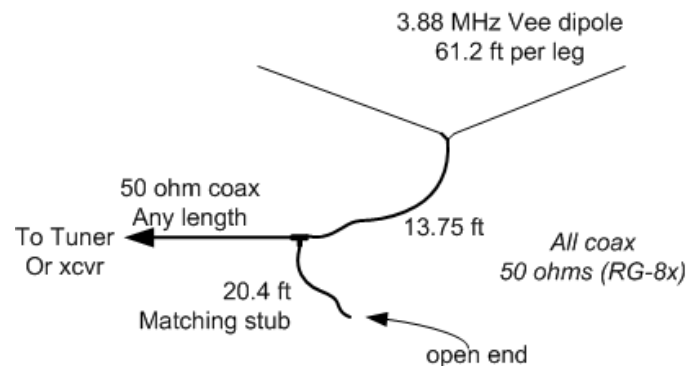
EZNEC sez:

- Opening up the angle on the wires lowered the resonance slightly (to 3.82 MHz).

- At the antenna feed point, the SWR increased to 1.24 and the impedance increased to $60.8 + j5.1$ ohms.

- I shortened both wires to 61.2 feet to bring the resonance back to 3.9 MHz. SWR increased still further, to 2.11 and the impedance at the feed point decreased to $24.2 + j6.9$ ohms.

- The in-line matching section and the tuning stub now look like this:



Result: resonant at 3.9 MHz; SWR = 1.1; Z seen by the xmtr = $52 - j4.3$ ohms.

I was surprised at what a big difference changing the angle of the antenna wires made.

This is all very interesting and educational, but it remains to be seen how it all stacks up against real-world results, when you get to actually putting the antenna up and trimming it to resonance.

Also, I found that if you just leave the matching stub off, the worst-case SWR should not be much greater than 2.2 (depending on feed line length). A good antenna tuner should take care of that. Of course, if you want to keep the losses to an absolute minimum, it's better to get the SWR down, and eliminate the antenna tuner. On the other hand, the losses at this low frequency are probably not bad, so ... take your choice.

I'm really interested in how this goes. Let me know if there are any more changes, or if you would like any more EZNEC modeling done.

This was more close to what I could so.

One weekend in July my friend JT WA1TDH was in town. We made a few more measurements and swapped out the dipole. I later made basic measurements of the new dipole and determined that the initial resonant frequency was 3.5 Mhz,

instead of 3.880. It took a month or two for me to get back to the project and trim the dipole ends. One reason for waiting is copper antenna wire tends to stretch a little bit after it is in the air. Trimming took a couple of hours as each time I would lower an end, fold back a bit of length at the ends, put it back up, then measure. Ground proximity made a BIG difference on the resonant frequency. I finally got the dipole to be resonant at 3.887 Mhz with an SWR or 1.5:1, which is "close enough for government work".

As indicated in Larry's drawing, I should have a matching stub to help bring the impedance to an exact 50 ohms. I tried a relatively short (25 feet or so) piece of coax, and this did not materially improve things, so I left it out. This dipole seems to be working fine, but I did not have anyone take S-meter readings before replacing it. With my current layout, I could use raising the left leg a bit, and may try to borrow a sling-shot or bow and arrow to do so.

An optimum antenna would be a straight dipole up about 70 feet. I cannot do this at my QTH. I have been thinking of trying out a loop antenna sometime, possibly for 160 meters. In summary, the new dipole is working, the jury is out on how much better the new antenna is. This process was a fun learning adventure and I now have a better understanding of transmission lines and ground proximity effects of antennas. Many thanks to Larry K1QW for all his effort, Peter W1ZZZ for the use of his MFJ259 antenna analyzer and JT WA1TDH for assisting me in raising the new antenna.